

Description

PROCESS OF END-FORMING A TUBE HAVING INTERNAL SURFACE FEATURES

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 60/319,561, filed September 19, 2002.

BACKGROUND OF INVENTION

FIELD OF THE INVENTION

[0002] The present invention generally relates to processes for forming the end of a tube in which internal surface features are present. More particularly, this invention relates to a process by which the end of such a tube can be reduced and the surface features removed during an end-forming operation while achieving accurate control of the tube outer diameter.

DESCRIPTION OF THE RELATED ART

[0003] Tubes for cooling equipment are often formed to have internal surface features in the form enhancements, which

may be described as flutes, ribs, etc., that are present on the internal circumference of the tube to promote heat transfer. Such a tube 10 is represented in Figures 3 and 4, in which the latter is a cross-sectional view of the tube 10 showing internal flutes 12 projecting radially inward from the internal circumference 14 of the tube 10. Internal enhancements of the type shown in Figures 3 and 4, are typically formed during drawing of the tube 10, and are therefore present along the entire tube length.

[0004] In the situation depicted in Figure 3 in which the tube end 16 is required to undergo an end-forming operation to reduce its diameter, the flutes 12 can interfere with the reduction process and excessively restrict flow through the tube end 16. Therefore, flutes 12 and other internal enhancements are often removed, such as by machining. However, the additional machining step and resulting possible contamination from chips are undesirable. An alternative approach is to remove the flutes 12 during the end-forming operation by using a die to reduce the outer diameter (OD) of the tube, after which the OD die is removed and an inner diameter (ID) mandrel is passed through the reduced portion of the tube. A disadvantage with this approach is that the mandrel can alter the OD of

the tube 10, making it difficult to obtain or control the OD of the tube 10.

SUMMARY OF INVENTION

[0005] The present invention provides a process by which the end of a tube having at least one internal surface feature can be reduced and at least a portion of the surface feature eliminated from the tube end during an end-forming operation while achieving accurate control of the tube outer diameter. The process preferably makes use of a forming tool comprising an external die for reducing the outer diameter of a tube and a mandrel for deforming the internal passage of the tube. The process of this invention generally comprises the steps of forcing the external die over the end of the tube so that the outer diameter of the tube end is reduced and so that the mandrel is simultaneously inserted through the internal passage of the tube end, during which time the mandrel is positioned farther within the tube than the portion of the tube end reduced by the external die. While the tube end remains within the external die, the mandrel is withdrawn from the internal passage of the tube end to eliminate the internal surface feature, preferably by deformation without physically removing the material defining the internal surface feature.

Because the tube end remains within the external die during elimination of the internal surface feature, the desired outer diameter of the tube can be maintained.

[0006] Other objects and advantages of this invention will be better appreciated from the following detailed description.

BRIEF DESCRIPTION OF DRAWINGS

[0007] Figures 1 and 2 represent steps in a process for end-forming a tube having a fluted internal diameter in accordance with this invention.

[0008] Figures 3 and 4 represent a tube of a type that can be end-formed in accordance with this invention.

DETAILED DESCRIPTION

[0009] Figures 1 and 2 represent a process for performing an end-forming operation on a tube with one or more internal surface features, or enhancements. In Figures 1 and 2, the tube undergoing end-forming is represented as the heat exchanger tube 10 shown in Figures 3 and 4, though the invention also encompasses end-forming of tubes with internal surface features that differ from that shown in Figures 3 and 4.

[0010] Figures 1 and 2 represent the end 16 of the tube 10 as undergoing deformation with a tool 20 in accordance with

a particular embodiment of the present invention. The tool 20 is shown as comprising a holder 22, an outer diameter (OD) die 24, and a mandrel 26. The mandrel 26 is located at one end of a shaft 28 secured within an internal bore 30 of the holder 22. The OD die 24 is tubular shaped and slidably received within the internal bore 30 of the holder 22. The OD die 24 has a stepped bore 32 within which the mandrel 24 is received. In this configuration, the position of the mandrel 26 relative to the holder 22 is fixed, while the position of the mandrel 26 relative to the die 24 varies as the die 24 is allowed to move within the holder 22, e.g., as the holder 22 is retracted in the direction of the arrow in Figure 1.

[0011] The bore 32 of the die 24 is shown as defining an internal die cavity 18 having a chamfer 34 at its entrance. As evident from Figure 1, the internal diameter of the die cavity 18 is less than the original outer diameter of the tube 10 (i.e., that portion of the tube 10 outside the die 24 in Figure 1). Moving the tool 20 toward the tube 10 (or moving the tube 10 toward the tool 20) to force the die 24 over the tube end 16 causes the tube end 16 to be reduced in diameter as it passes through the chamfer 34 and into the die cavity 18, with a tapered shoulder 17 being defined

between the reduced tube end 16 and the remainder of the tube 10 as represented in Figure 1. Prior to initiating the end-forming operation represented in Figure 1, the die 24 is retracted into the holder 22 so that the mandrel 26 is either circumscribed by the chamfer 34 (as shown in Figure 1) or projects outside the bore 32. This positional relationship between the mandrel 26 and die 24 is maintained throughout the end-forming operation represented in Figure 1, so that the mandrel 26 remains positioned interiorly of the tapered shoulder 17 produced on the tube 10 by the chamfer 34. The die 24 may be forced over the tube 10 until the tube 10 abuts the shaft 28. The entire reduction process portrayed in Figure 1 can be performed in a single impact or multiple impacts.

[0012] As evident from Figure 1, the mandrel 26 is preferably smaller in diameter than the enhancements 12 to be removed, and therefore does not alter the enhancements 12 during reduction of the tube end 16. However, Figure 2 shows the mandrel 26 is having roughly the same diameter as the circumference 14 within the reduced end 16 of the tube 10, such that removal of the mandrel 26 through the reduced end 16 of the tube 10 necessarily results in at least partial elimination, and preferably complete elimina-

tion, of the enhancements 12 within the reduced end 16 of the tube 10.

[0013] Figure 2 represents a second step of the end-forming process during which elimination of the enhancements 12 occurs. Figure 2 illustrates the result of the holder 22 having been moved in the direction of the arrow, causing the mandrel 26 to also move in the direction of the arrow in view of the attachment of the shaft 28 to the holder 22. As the holder 22 and mandrel 26 move away from the tube 10, the die 24 is able to remain on the reduced tube end 16 as a result of the die 24 being reciprocally received in the bore 30 of the holder 22. In fact, the die 24 remains on the tube end 26 as a result of the inherent diametrical interference that exists between the die 24 and the tube end 16 following the reduction operation. As such, no additional means are required to retain the tube end 26 within the die cavity 18. The relative movement between the mandrel 26 and die 24 causes the mandrel 26 to be withdrawn from the tube end 16. As stated above, the mandrel 26 is sized so that the interior of the tube end 16 is deformed to the extent that the internal enhancements 12 within the reduced tube end 16 are flattened, preferably to the extent that all vestiges of the en-

hancements 12 are eliminated without removing any material from the tube 10. In so doing, the mandrel 26 simultaneously applies a radially-outward force on the wall of the tube end 16, causing an increase in friction between the die 24 and tube end 16 so that the tube end 16 remains within the die cavity 18 throughout withdrawal of the mandrel 26 through the tube end 16. During this process, the outer diameter of the tube end 16 remains constant as a result of being held within the die cavity 18.

[0014] While the invention has been described in terms of a specific embodiment, it is apparent that other forms could be adopted by one skilled in the art. For example, the tool 10 could differ in appearance and construction from the embodiment shown in the Figures. Accordingly, it should be understood that the invention is not limited to the specific embodiment illustrated in the Figures. It should also be understood that the phraseology and terminology employed above are for the purpose of disclosing the illustrated embodiments, and do not necessarily serve as limitations to the scope of the invention. Therefore, the scope of the invention is to be limited only by the following claims.